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EASTERN IOWA LITHICS AND THEIR EFFECTS
ON ONEOTA CULTURE

A Thesis Submitted
in Partial Fulfillment
of the Requirements for the Designation
University Honors with Distinction

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University of Northern Iowa
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This Study by: Caitlin Kelly

Entitled: Eastern Iowa Lithics and their Effects on Oneota Culture

has been approved as meeting the thesis or project requirement for the Designations University
Honors with Distinction.

Date

Dr. Chad Heinzl, Honors Thesis Advisor, Department of Earth Science

Date

Dr. Jessica Moon, Director, University Honors Program

Abstract

This research focuses on the experimentation and exploration of heat treatment used on chert by the Native Americans located in eastern Iowa after the Late-Woodland Period. In conjunction with my research advisor, Dr. Chad Heinzl, the geoarchaeologist in the UNI Department of Earth Science, I have heat treated chert from eastern Iowa in order to examine its physical and chemical changes. These experiments took place both in a controlled laboratory setting and in a semi-controlled field setting, comparing the difference between the two different methodologies. Chemical analysis was also performed to assess differences in trace chemicals between raw and heated chert. The results and data gathered from my experiments showed a change in coloration during heat treatment and a range of fractionation rates that depend on the intensity of heat. Chemical traces provided interesting data that opens another avenue of future study to examine the chemical changes prompted by heat treatment. Ultimately, I used the results from my experiments to examine how they affect the quality of chert and, in turn, how that affects Native American culture and trade. Specifically, I looked at the presence of different types of chert and how that connected to the culture of an eastern Iowa tribe called the Oneota. Trade especially would have been affected by the presence or absence of high quality chert and the impact of my conclusions adds knowledge and a new perspective to the studies on Native American culture and material trade.

I. Introduction

Archaeological evidence on Native American tribes have found that tribes in the US and across the world have used heat treatment on their local rocks in order to draw out useful qualities in regards to stone tools. One widespread culture in eastern Iowa was the Native American Oneota tribe. Examination of Oneota archaeology has shown that they used heat treatment, or the heating of rock, on their local chert. Chert, sometimes known as flint, is the most commonly used rock in Native American stone tool creation. Examination of the use of heat treatment of chert by the Native Americans can shed light on their innovations and methods of survival, furthering current knowledge on culture and trade.

The purpose of my research was to conduct experimentations through heat treatment of chert in order to observe the effects it has on this raw material. The results from these experiments were then used to interpret how Native American tribes would have found these resources and utilized them in making stone tools, such as arrow points. I explored the physical and chemical signatures of eastern Iowa's lithics, or sedimentary rocks, in both controlled laboratory and semi-controlled field settings in order to determine the effects heat treating has on appearance and fractionation. I also delved into how these raw materials were incorporated into Native American trade and hunting, specifically the culture of the Oneota tribe in eastern Iowa. Some research has been done into the field of heat treating lithics, and my research and experiments contributed to this field with more specialized testing using x-ray fluorescence, while also providing links to how heat treatment of chert effected Native American culture.

As this research addressed several intertwining concepts – those of physical and chemical changes as well as cultural implication – several research questions were needed to link the ideas together. On the geological level, how does heat treating affect chert from eastern Iowa deposits

in regards to chemical and physical properties? Native Americans utilized heat treatment to enhance the chert, but exactly how heat treatment effects the lithic is important to find out. Since the Native Americans did not use modern ovens to heat their rocks, I used field experimentation to evaluate how they would have heated their lithics. A comparison between the laboratory heat treatment of chert and the field experimentation was drawn in order to observe differences in results. Lastly, how the quality of the heated lithics affected the spread of the Oneota tribe in eastern Iowa was examined. The relationship between heat treatment and raw quality of chert is important and applying the results of my laboratory and field experiments to the Native American archaeology of eastern Iowa gave new insights into Oneota culture and trade. These new insights into the geoarchaeology of Iowa contribute to a growing knowledge of how Native Americans traded and spread their culture across North America, shedding light on how they lived and the innovations that they used to survive. In order to begin my experimentations, I first examined past research and theories in both the geology and archaeology of Iowa and Native American lithic use.

II. Definitions

As much of my research is scientific, I would like to explain a few of the terms that I use throughout my paper so that they are not confusing.

Chert – a type of sedimentary rock that is commonly used by Native Americans in stone tool creation, also known as flint.

Conchoidal fracture – a type of curved fracture that occurs in lithics such as obsidian, flint, and chert that produces sharp edges.

Flint – another word sometimes used for chert, generally applied to the darker gray and black chert that is found in limestone deposits.

Fracture – a fracture is a crack or break in the rock that can occur because of heating.

Fragments – approximately quarter-sized pieces of chert used to examine heat treatment effects on smaller samples.

Lithic – another word for a sedimentary rock, such as chert.

Oxidation – a change in the samples due to the introduction of oxygen and heat.

Quartz sand – sand-sized, rounded pieces of quartz commonly used during geological experimentations.

Rockshelter – a cave or similar formation used by Native Americans as a ritual shelter and, in some cases, a seasonal shelter for hunting.

III. Literature Review

A. Geology

Northeast and east-central Iowa provide low- to medium-quality chert in the Ordovician, Silurian, and Devonian strata while southeast Iowa provides large pieces of high quality Mississippian chert (Figure 1). The white mottled chert of the Burlington strata in southeast Iowa is an example of a high quality chert that can be found in large pieces (Morrow, 1994).

There are several ways to characterize chert including, but not limited to, color, texture, and luster. Color is one of the most noticeable, but also one of the least useful categorizing tools; natural colors of chert vary greatly and different types of chert do not exist in only one shade. Along with natural color variations, heating can also produce a varied amount of colors, although reddish hues are the most common. Color patterns, including mottling, marbling, and speckling, are more useful in examining unique traits of cherts. Texture refers to the size of the crystals and is very helpful in separating raw materials as well as within specific varieties of heat treated chert. Because of the vitreous luster that often occurs with heated chert, luster is another helpful tool in identifying heat treated rocks (Morrow, 1994). These are the common identifying tools in

differentiating between rocks in general, but since heat treated rocks differ physically and chemically from their raw source rock, using them as tools to help identify between the two types of rock is also viable.

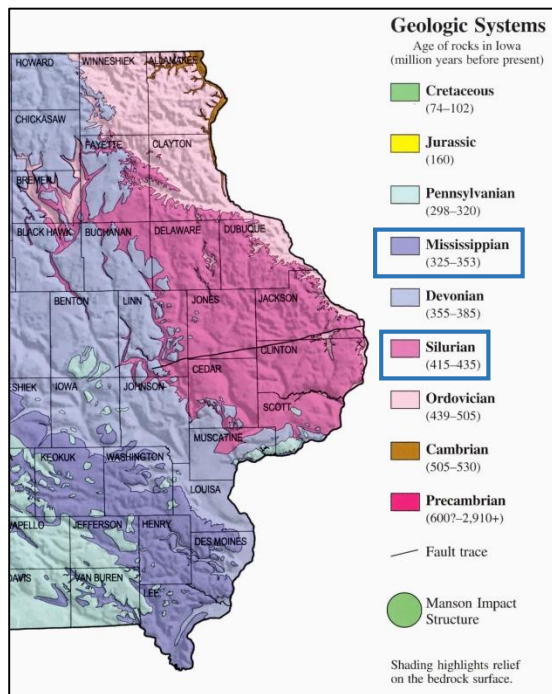
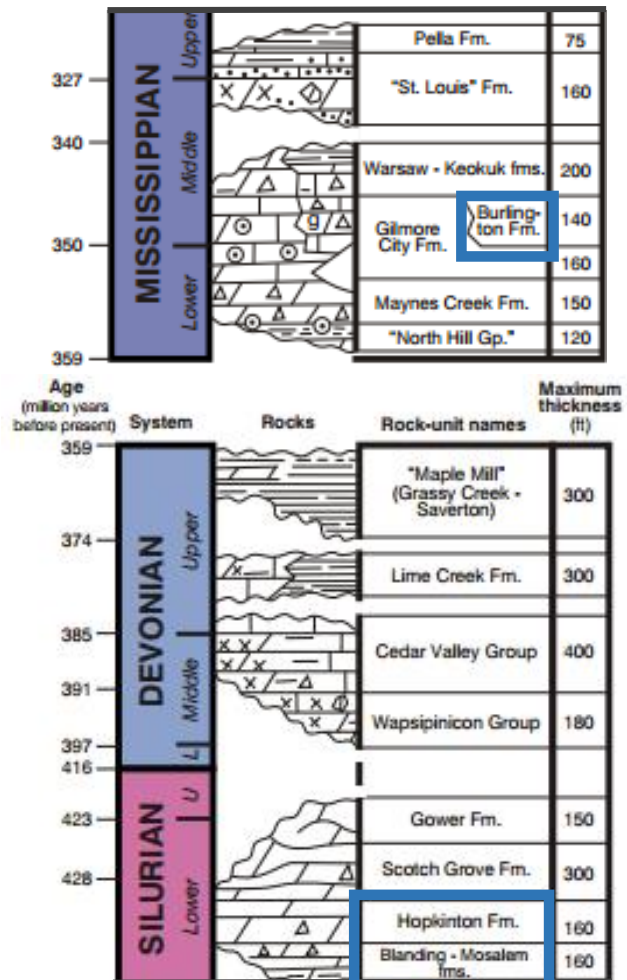


Figure 1. Stratigraphic column of Iowa's Silurian, Devonian, & Mississippian time periods (right). Eastern Iowa geologic map (below). Column and map courtesy of the Iowa DNR.



Other identifying features include the presence and types of fossils found in the chert. Brachiopods, fenestrate bryozoans (a type of fossilized coral), and solitary corals are often found in Burlington and Keokuk chert Formation. Crinoids of five to ten mm diameters can also be found in Burlington chert. Massive coral can be found in the Hopkinton Formation. The Blanding Formation, another Silurian Formation containing heavy amounts of chert, can also be found in northeast and central Iowa, also spilling into Illinois (Anderson, 1998). Many of the

fossils that can be found in the Hopkinton can also be found in the Blanding, and it can be hard to tell the two formations apart (Anderson, 1998). Morrow (1994) provides a key to help deduce what type of raw material an archaeological sample contains. Several Iowa chert formations and their characteristics and archaeological significance differ, and can be differentiated by their location and description. The Hopkinton Formation is found in northeast and east-central Iowa and Hopkinton Chert can resemble Burlington Chert, but they rarely have bryozoans and contain smaller crinoids (Morrow, 1994). Burlington, white mottled, chert is the most common and widespread lithic material in the state. It is extremely common in southeast Iowa, but also occurs frequently, although in smaller amounts, throughout the state. It was a preferred material for Paleoindian and Early Archaic (8000 BCE) projectile points and knife tools, and has lasted a long time, also found widely circulated among the Oneota during the Late Prehistoric period (Morrow, 1994). The Burlington Formation itself stretches across the Midwest, existing underneath several different states around Iowa. It is very well known for producing chert and flint used by Native Americans, and the city in Iowa now named Burlington used to be called Flint Hills (Anderson, 1998). This higher quality of the chert and its circulation also play an important role in the archaeological background, especially in regards to the Oneota.

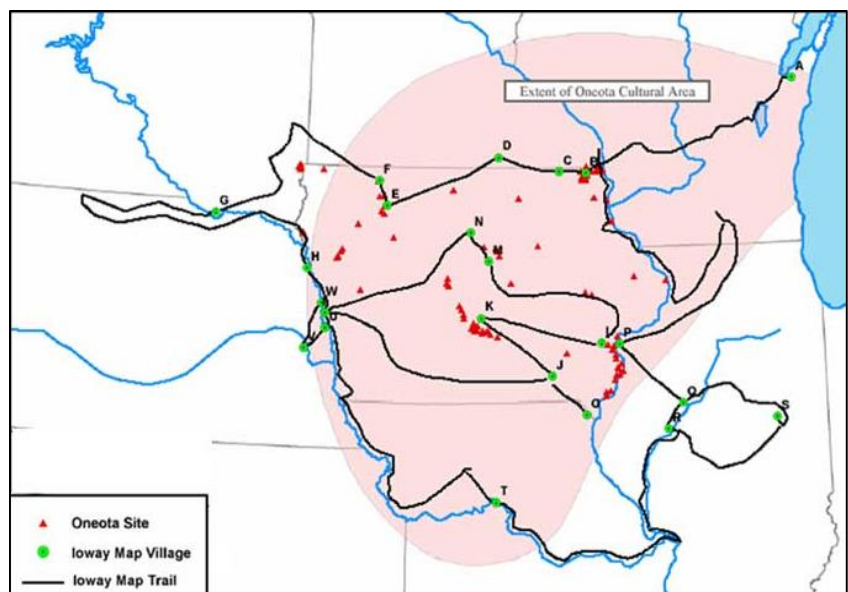
B. Archaeology

Oneota Culture

The Oneota were a Native American tribe that was spread across the upper Midwest during the late prehistoric Mississippian period of about 1200 to 1650 BCE (Figure 1). The Oneota started to take over eastern Iowa around 1300 BCE, fully spread out after the end of the

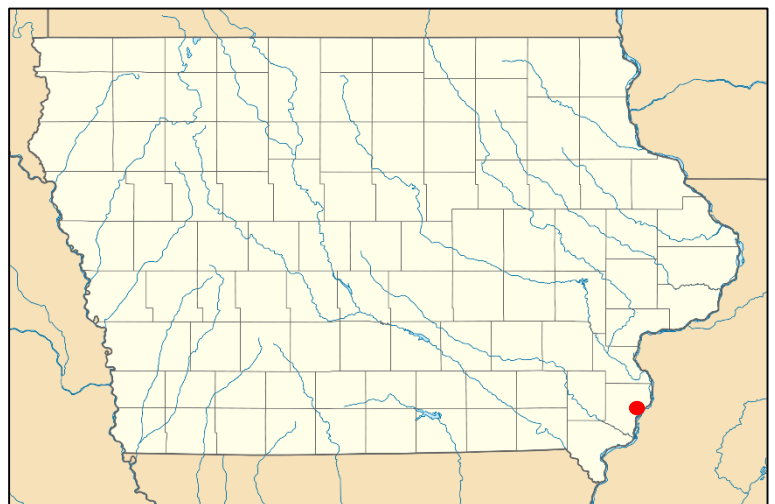
Late Woodland period. They lived off of a combination of maize agriculture and hunting and gathering subsistence methods, with the latter being slightly more prominent (Hart, 1990). Maize was a very common subsistence crop among societies in that area, several theories have been put forth regarding this difference in the Oneota. One theory, which used to be more prominent, proposes that because of some climate changes, the Oneota became more mobile and relied less on maize and more on big-game hunting. A theory that has gained some momentum recently proposes that, because of the shorter growing season in the upper Midwest, the crops could not be relied on quite as heavily as in other areas (Hart, 1990). Other theories suggest that an existing low-density population, rather than climate, caused the lack of reliance on maize. Oneota tribes varied in population density, so some tribes may have relied more on maize agriculture than others (Hart, 1990). The leading theory for the emergence of the Oneota is that they were descendants of the Wisconsin Effigy Mound culture, whose people mingled with the Mississippians, and were introduced to maize agriculture and new technologies (Birmingham, 2000). Whatever the cause of the new culture or subsistence style, the Oneota needed the natural chert that they could find in order to survive, and the higher quality chert they had access to, the easier it was to make stone tools and use them.

Figure 2. Map of Oneota territory at its most extensive. Map courtesy of the University of Iowa Archaeology Department at <http://archaeology.uiowa.edu/1837-ioway-map-and-gis-0>.



The majority of Oneota sites rest on the eastern side of the Missouri River along southern Minnesota, Iowa, Wisconsin, Illinois, and Missouri (Figure 2). Iowa is the geographical center of the Oneota culture and dating estimates put their formation around 900 BCE and lasting until around 1600-1700 (Straffin, 1972). Their pottery are their most well-documented remains and consist of buff to buff-gray, shell-tempered vessels of varying sizes. The Kingston Oneota site in southeastern Iowa (Figure 3) lies next to the Mississippi and is one source of information for the Oneota (Straffin, 1972). Artifacts gathered there included bones, lithics, and ceramics characteristic of the Oneota culture. Some trade items, such as foreign pottery and the like, were also found; this suggests that they had a certain amount of contact with other tribes not from the southeastern region that they had established a trading relationship with. Two concentrations of burned earth were found in the site that might be related to the firing of lithics. The southeast area provided a natural route for Plains and Middle Mississippi Native Americans (including the Oneota) to trade between each other (Straffin, 1972). The natural trade route was created by the numerous river systems, mainly the Mississippi and Missouri Rivers, and the broad plains that stretch across Iowa. Easy access to other tribes and a desire for different types of pottery, lithics, or other materials would have strengthened ties between tribes and increased trade.

Figure 3. A map of Iowa with the Kingston site marked in the southeast corner, next to the Mississippi River. Map courtesy of https://commons.wikimedia.org/wiki/File:USA_Iowa_location_map.svg.



A more recent study examined the shift from Woodland Period cultures to Oneota and brought forth more recently discovered data together to examine how this shift occurred and what aspects of Oneota culture developed. The Late Woodland Effigy Mound Culture that relied on hunting and gathering was replaced by the Oneota culture, which revolved around agriculture, wetland resources, and bison hunting, sometime between 950 and 1150 BCE (Theler and Boszhardt, 2006). This transition, as seen from the above articles, has been contested for decades as to how and when it happened; the approximate date has been narrowed down to the 200 years just mentioned, but a narrowed time scale has not been proposed. The shift does not overtly appear to be either a takeover of a new culture or people or a change to newer technology, but either are possible, although a shift in technology seems the more likely of the two. Much of the transition seems to be consistent with a switch from a hunter-gatherer society to an agricultural society, supported by a continually denser population. Different factors found in this shift included the packing model of the population density, game shifts (what type of animals were hunted), warfare, and settlement pattern shifts (Theler and Boszhardt, 2006). The leading emergence theory combines the two avenues of cultural change – a new people/culture and a change in technological use (Birmingham, 2000). Shifts in subsistence patterns and societies is often accompanied by shifts in technology or use of technology, which may have caused the new society to use more of the lithics they found, or find ways to make them work better or last longer.

Artifacts of the dying Effigy Mound Culture included Madison pottery and Madison Triangle projectile points (with occasional Cahokia and Grant side-notched varieties) that was made from local chert sources. The Effigy Mound Culture saw changes around 950 BCE through the introduction of maize and a more constricted mobility (Theler and Boszhardt, 2006). The

bow and arrow and floodplain resources also came into use. Arrow tips for this culture went through phase changes throughout their periods; from 500 to 700 BCE, there were Honey Creek Corner-Notched points, but by the Late Woodland period the Madison Triangular points dominated (Figure 4). These unnotched tips were consistent with warfare and remained common into Oneota Culture. Rockshelters were widely used as winter camps as a base for deer hunting, and later for bison hunting (Theler and Boszhardt, 2006).



Figure 4. Madison Triangle arrowheads recovered from an archaeological dig. Photo courtesy of <https://www.southalabama.edu/archaeology/madison-park-lithic-analysis-02.html>.

From 1050 to 1200 BCE, Woodland and Middle Mississippian cultures started to blend and change as the Middle Mississippian societies moved across the Midwest. Powell and Ramey pottery and tri-notched projectile points became common in these areas. Several of the Oneota sites include Moingona sites in central Iowa, Dixon and Mill Creek in northeastern Iowa, and the McKinney and Wever Terrace sites in southeastern Iowa (Theler and Boszhardt, 2006). Oneota sites were well established by 1200 BCE and had characteristic pottery of shell-tempered globular jars, settlements constructed with wigwams and longhouses, and bison iconography (Theler and Boszhardt, 2006). Many of these settlements showed a seasonal shift; during the winters, many communities would migrate west of the Mississippi River to hunt the bison they prized so much. This seasonal migration might have caused connections with other cultures in the west, whom they could trade with during their nomadic periods. Excursions were mostly used for hunting, lithic resource procurement, and ritual use of the rockshelters (Theler and Boszhardt, 2006). Travelling seasonally would have given the Oneota greater access to more

types of lithics, including higher quality raw chert or more quantities of low quality chert that they could still use.

Eastern Iowa Lithics

Chert is the most common stone found in archaeological chipped-stone assemblages. It is not as desirable as obsidian, but both are valuable because of their ideal conchoidal fracturing. Flint, a more commonly well-known term, is used to describe the dark gray or black chert, especially those found in limestone deposits (King, 2015). Larger lithics are normally found closer to their raw source, and archaeological evidence has found that heat treatment generally occurs near the raw source as well. Heating was often done at or near the raw source in order to weed out flawed stone and to reduce the amount of stone that has to be transported (Morrow, 1994). Figure 5 shows an example of a chert outcrop that has been exposed because of underground stream systems. Later stages of flaking usually occur farther away from their original source of raw material. Those lithics found farther from their source tend to be of higher quality; they have to be tough to last long enough to travel farther away and they must have come in large enough pieces that they could be worn down continually and still have material left. High quality, larger pieces would also have been enviable for trade, especially to those groups who did not have high quality stones of their own. However, the rock can be moved away from its source because of natural causes, like glacial or river movements, as well (Morrow, 1994).

Figure 5. A section of the outcrop in southeast Iowa where I gathered the Burlington Formation chert. Photo courtesy of https://www.geocaching.com/seek/cache_details.aspx?wp=GC1H6DM&title=blackhawk-spring-earthcache&guid=3c365771-411c-48ad-81a0-7ee820c848a9.



C. Geoarchaeology

Stone tools were originally developed to help increase the success of food gathering and processing so that early humans could hunt more effectively. These tools were more advantageous if they were sharper and sturdier, but when Native Americans did not have access to higher quality lithics, they would either trade for them or use controlled heat treatment to draw out some positive attributes. Deliberate use of this technique can be dated back to at least 72,000 years ago in Africa, when fire was beginning to be used as a way to effect the environment. This treatment has also appeared as far back as 164,000 years ago, but it was only 72,000 years ago that it began being practiced regularly in Africa (Schmidt et al., 2012). The rocks were buried beneath a burning fire for at least a day and then dug up and fashioned. In Australia, another technique was to build up a fire and, when it burned out, to dig up the coals in order to place the lithics in the sand. They were covered with an insulating layer of cool sand and then the coals and hot sand would be placed on top and left to smolder and heat the rocks for three or four days. Pressure or percussion (through striking the rock) flaking was then used to work the lithic into a usable, sharp point. Microcrystalline siliceous rocks (chert, chalcedony, and jasper) work best for flaking, but the fractioning is much improved through heat treatment. It provides greater control, ease, and precision in flaking than if a raw rock were worked on. The heating works to recrystallize the structure and heal microcracks that could result in unintentional fractioning in a raw sample. This method works especially well when creating blades, microblades, and bifacial points (Webb and Domanski, 2009).

Other byproducts of heating include a color change, usually to a reddish hue, and the addition of a vitreous luster on the outside faces. Heat treatment was often used to improve the quality of the raw material or to conserve the material, since more points could be produced out

of a heated stone than an unheated stone of the same size, due to its increased workability (Webb and Domanski, 2009). Therefore, in using heat treatment, Native Americans could have taken greater advantage of lower quality chert or a lesser amount of chert, making it last longer than it would have lasted when it was unheated and raw.

Chert is one of the most, if not the most, common lithics used in Iowa prehistoric technology. For decades there has been the belief that some societies heat treated the chert before shaping it into tools, but it was not until recently that this method has been taken seriously. Many methods have been tested to see how prehistoric humans heat treated the chert, attempting to recreate the post-treatment characteristics seen in the rocks. Although it can happen naturally, a common indication of heat treatment in a chert is a pink or reddish color or a vitreous luster. Electron microscopy and x-ray diffraction have been used to examine the crystalline structures of raw and heat treated cherts (Melcher and Zimmerman, 1977). Thermoluminescence (TL) has been successfully used in dating ceramics, so it has begun to be applied to chert to see if there is a chemical difference in the TL levels that can distinguish raw from heated chert. It was found that there was a difference; unheated TL levels were typically 100 times greater than those cherts heated in the last several thousand years. The TL test reliably detects the heating levels, partially due to its prior use on thermoluminescence levels in ceramics, but it does not determine *how* the chert was heated – it could have been intentional or accidental and the TL levels would not show a difference (Melcher and Zimmerman, 1977). Accidental or unintentional heating could occur through forest fires or just regular hearth fires; it is best to examine the heated chert to ascertain that the cause of firing was due to intentional heat treatment (Gregg and Grybush, 1976). Another shortcoming is that the TL testing becomes less useful with older samples; the farther back a rock was treated, the more its TL levels appear like an unheated rock (Melcher and

Zimmerman, 1977). Since many stone tools recovered from Native American sites are relatively older, this presents a problem that prompts a solution that can inspect the rocks equally no matter the age.

Mass Analysis (MA) can be applied to the debitage, or flaking by-products, of stone tools in order to examine the characteristics of these tools. MA provides a rapid, objective, and efficient testing of debitage that is useful when examining large quantities of material. Through MA testing, different styles of production can be examined and separated; hammer reduction, projectile point manufacture, bifacial thinning, and bipolar reduction of pebbles. However, this technique of testing may be taken for granted and not thoroughly looked at, so its efficiency and simplicity may be accidentally taken as accuracy. Problems with Mass Analysis include its claims to recognize debitage technique similarities, but it does not take in replicator variability and the differences between individual styles. Variability in the raw material, as well as its original shape and size, can also affect how it is sorted and that is not always taken into consideration when using MA. Debitage mixing can also occur, which happens quite often in the archaeological record, and that can throw off MA results. There are other examples, but the main idea is that one technique is not going to burst open all of the secrets of heat treatment on lithics; it is best to critically examine the results of testing and to redo them many times so as to be assured of the outcomes (Andrefsky, 2006). In this vein, using newer technology and more varied technology can help piece together the different aspects and variable involved in heat treatment.

The geology and archaeology of eastern Iowa combine to form a geoarchaeological view of how chert was used by Native Americans who lived in the area. Lithics would have been affected by their quality and that would have impacted how the Oneota used heat treatment when

trying to make them stronger or more durable. Knowing the background of these different aspects of chert and the Oneota are necessary for creating experimentations that hold historical and scientific significance. Many types of technology have been used in trying to examine the exact methods that were used in heating chert and what exact outcomes were produced. However, more experiments and research needs to be done in order to evaluate the process and consequences of heat treatment.

IV. Research Methods

The first half of my research concerns the scientific experimentation and observation of heat treating and chemically testing the lithics. This portion of my methodology occurred mostly during the spring and summer of 2015 and was finished by the end of August, 2015.

Materials:

- Chert samples
- Quartz sand
- Natural surface soil
- Tin containers
- Porcelain containers
- Three ovens measured at 250°, 300°, and 600° Celsius
- Heat protective gear (glasses, gloves, tongs, etc.)
- ExTech IR High Temperature Thermometer 42545 (heat detecting tool)
- Lab notebook
- Pencil/pen
- Camera
- Hammer
- Safety goggles
- Spex 8000 Mixer/Mill (reduces rock to powder)
- X-Ray Fluorescence machine
- XRF preparation materials
 - Including storage and testing containers, a shelving unit designed to hold the samples, and a labelling machine
- Field testing materials (fire building materials, open space, surface soil, etc.)

Collecting Materials

The first stage of my research was the obtaining of appropriate lithics to use for experimentation. Two formations that I concentrated on were the Hopkinton and Burlington Formations. I was able to take several field trips to southeast Iowa in order to obtain the Burlington Formation chert from an outcropping located along the Mississippi River. My advisor, Dr. Chad Heinzl, was able to procure chert from the Hopkinton Formation in northeastern Iowa during some of his trips to the area. Once the rocks were gathered, they had to be cleaned, sorted, and adjusted for size. Many pieces of the chert were too large to fit into the ovens, they were broken into more workable pieces. Using a hammer, I was able to break them into segments of approximately two or three inches long by one to two inches wide, with a depth of about one inch. Some of the pieces were smaller, but that factor did not have an observable effect on the results of the heat treatment. The chert was then sorted and labelled so that there were the same number of Burlington and Hopkinton Formation samples dedicated to the 300°C and 600°C ovens. Smaller fragments of chert that broke off during size reduction were used in the 250°C oven to examine how the heat affected smaller pieces of chert. Once the size reduction and sorting was finished, I could begin experimenting with heat treatment.

Laboratory Experimentation

The next part of my scientific experimentation took place in the laboratory. This part of the research began in the spring and was completed by the end of summer, 2015. The following are the steps I used in order to treat the chert.

1. Heat three ovens at 250°, 300°, and 600° Celsius for the lab portion of the testing
2. Make sure Hopkinton Formation chert is separated equally into groups for the 300°C and 600°C ovens
3. Prep tin containers with quartz sand – put first two samples into separate containers
4. Insert first two samples into 300°C and 600°C ovens
5. Heat ovens for approximately two hours, or until they are heated to correct temperatures
6. Keep in oven for between three and six hours
 - a. Turn ovens off at the appropriate time
 - b. Do not remove containers right away, as that might cause damage to the ovens from rapid cooling
 - c. Remove the containers after several hours or the next morning
 - d. Turn the ovens back on to warm up for a couple hours before the next set of chert can be inserted
7. Repeat steps 2 through 6 for tin containers with surface soil
8. Repeat steps 2 through 7 for porcelain containers
9. Repeat steps 2 through 8 for chert fragments in the 250°C oven
10. Repeat steps 2 through 9 for the Burlington Formation chert
11. Record results

As stated before, the ovens were used for differently sized chert depending on the temperature. The 250°C oven was used for fragments to see how smaller pieces of chert were affected by heat treatment, while the 300°C and 600°C ovens were used for the larger pieces of chert. The fragments were prepped in the same way but tested only in the 250°C oven. I was able to simultaneously heat a piece of chert in each of the three ovens. However, since the whole process took approximately six to eight hours with the ovens on and an additional 3 or more hours to cool down, one set of rocks was all I was able to test each day, with two rocks per set. Using this process, I was able to test approximately 50 samples of Hopkinton and Burlington Formation chert.



Figure 6. (Above) Samples ready to be tested in quartz sand.

Figure 7. (Right) 600°C oven with a tin container and sample inside.



Field Experimentation

The next part of the experimentation stage was testing the lithics in semi-controlled field settings. This stage of the research occurred mostly during the late spring and throughout the summer months, in order to ensure that the ground was not frozen. It was completed by the end of August, 2015. The following is the general process that Dr. Heinzl and I used while testing the chert in the field setting, followed by an in depth examination of the specific details and materials.

1. Create a 12 to 14 inch hole within an existing fire pit
2. Place the rocks into the new hole and cover with approx. two inches of soil
3. Create a fire on top of the rocks and keep the fire going for approximately 8 to 24 hours
4. Partially cover the remaining coals with more soil and leave to bake over another 12 hour period
5. Uncover and examine for post-firing properties

According to Dr. Heinzl and some of my previous literature research, this is a possible method that the Native Americans might have used while heating their own chert. Even if it is

not the exact method that they used, it involves several aspects that I found throughout my research on Native American heat treatment methods (Schmidt et al., 2012). Whereas the laboratory testing used ovens with controlled heat measurements concentrated on the chert containers, that type of focused energy is not as readily available in field settings. Instead, Native Americans would have used open fires to heat their chert. However, they could not simply throw the rocks into the fire as that would result in too much fracturing and the heated rock would be either unusable or break after one use. Therefore, they could bury the rocks underneath the fire so that the hottest part of the fire – the core of the wood and lower center of the flames – would be close to the rocks. With this method they could heat the chert without fracturing it to an unusable extent.

For my field experiments, I used the burial method to treat the chert. Dr. Heinzl and I implemented this process on his farm in northeast Iowa, using the Iowan surface soil and an existing fire pit. We dug the hole several inches deep through the soil and coals and placed the raw chert pieces in the indentation (as seen in Figure 8). We then covered the rocks with approximately two inches of the coal and surface soil we had just displaced. Then we used Red Elm, twigs, and corn husks to build a fire on top of the covered chert. After that, we kept the fire going for another eight or more hours, checking the temperature periodically. The temperature stayed steady at around 600° or 650° Celsius as it was fed and kept going. This temperature matched the higher oven temperature in the laboratory experiments but since the chert was buried underneath the fire and not in the center of it, the rocks had a temperature closer to that of the 300°C oven. This is the reason why we kept the fires going for so long. Since the chert did not get the direct, concentrated heat that the laboratory samples did, they needed a longer period of heating. This duration of heat offset the lack of concentrated heat.



Figure 8. An example of the field experiment fire pits with all of the rocks about to be heated inserted in the pit, which would then be covered with soil and then have a fire built on top.

Once the fire went out after its allotted time, the rocks were not done being heated. The still burning coals were then covered with another layer of surface soil in order to direct the heat towards the rocks below. Without the covering soil, the heat from the burning coals would have mostly dissipated into the surrounding air, but since it was covered, it could further heat the rocks. This cooling down and continued heating can also be seen in the laboratory experiments. After the ovens were turned off, the samples could not be directly taken out because the rush of cool air might damage the internal heated plates of the ovens, but this essentially simulated the continued baking of the fire pit. In both, the heat slowly dissipated over a period of hours but it continued providing more heat to the rocks as it did cool. This period of slow cooling also allowed a buffering period for the rocks – if they were exposed too quickly to cool or cold air then they would have fractured and been useless. The gradual cooling allows them to become adjusted to a new temperature without breaking apart. Once the coals and rocks cooled over approximately a 12 hour period, they could then be retrieved and made into stone tools. Unfortunately, we were only able to do three of these field experiments, but they were done consistently and the conditions can be recreated for future testing.

Chemical Testing

As I was heat treating the chert in the lab ovens, I was able to chemically test it. The following is the process I used while utilizing the X-Ray Fluorescence machine to examine the chemical compositions of the chert. This testing overlapped with the heat treatment and was completed during August, 2015.

1. Manually break rocks into fragments
2. Use the powdering machine to further break down the fragments until they have the consistency of powder
3. Prepare the samples by putting the powder into the special plastic containers provided for XRF use – label and store them correctly in XRF shelving unit when not being used
4. Insert samples into XRF machine
5. Begin testing for different chemical compositions

While separating the Hopkinton and Burlington Formation chert to use for heat treatment, I set aside some to be used for chemical testing. Along with this raw, or untreated, chert, I chemically tested some of the rocks after they were heat treated. The chemical testing then encompassed the raw chert, laboratory heat treated chert, and the field heat treated chert. In order to test the chert with the X-Ray Fluorescence (XRF) machine, the chert then had to be broken and crushed into a powder form that could be analyzed. Manually hammering the rocks was not enough, so I used a Spex 8000 Mixer/Mill (Figure 9) to powder the smaller fragments. The machine usually had to be on for about 10 minutes while it crushed the chert in a small porcelain container. After it was turned into a powder, I could then scrape it into small plastic containers that corresponded to the slots they were later be inserted into inside the XRF machine (Figure 10).

The XRF machine could hold up to twelve containers at once, but could only process them one at a time. In order to use the XRF machine, I had a connected computer and MiniPal

computer program that gave me the ability to adjust the test settings. Through this program I could adjust the time length, KeV measurement, type of filtered air, and various other settings. Concerning the time length, shorter times meant I could test the samples faster (because they could not be run simultaneously) but the longer time periods meant a more thorough reading of the chemical compositions. The KeV measurement was what could be adjusted to target certain chemicals. I could adjust the KeV level to target the chemicals I was looking for and it would recognize them easier that way. There were two choices for the type of air used in the XRF process; air or helium. I tested with air first, but that saw highly elevated levels of AU (gold) and AG (silver) which do not naturally occur in chert. I consulted Dr. Heinzl and we realized that it was the air that was being filtered that was causing the issue. Once we realized what the issue was, we were able to switch to the helium filter and I began rerunning the previous tests in order to obtain correct results. Most of the other setting choices were left alone as they were parameters set up for chemical testing.



*Figure 9. (Above) Spex 8000 Mixer used to powder the chert samples.
Figure 10. (Right) XRF Machine with samples inserted.*



Through the chemical testing, I was able to test two samples of the raw, laboratory tested, and field tested chert from both of the formations. I adjusted the KeV to four separate levels and was able to examine the results from each type of chert for each level for difference or similarities in the chemical composition. I then examined the results to see if there were any observable chemical changes in the sample compositions.

V. Results

Laboratory Experimentation

I was able to analyze 44 chert samples, half of them belonging to the Hopkinton Formation and the opposite half belonging to the Burlington Formation. Through my heating of these samples, I found two main changes in the physical composition regarding coloration and fracturing changes (examples of which can be found in Figure 11).

The coloration changes were examined using the Munsell color system, a system very commonly used in geological research to determine exact colors and shades of rocks and soils. The system is arranged by using letters and numbers, letters designating the general color range (Y means the yellow range, whereas Gley represents the greyscale, and YR refers to the yellow-red scale) and numbers specifying the exact shades. Raw chert can range in color from white and light gray (usually around Gley2 7/1 or Gley 8/N) to tan (approximately 2.5Y 8/1, 7/1, or 6/1) and even to darker, almost black, grays. Generally, the color can offer an evaluation of the quality of the chert; lighter color like white and light gray mean that there are less impurities and a higher quality of pure chert. Conversely, darker colors sometimes suggest the presence of more impurities – however, this is not always true, for example Knife River flint is dark gray or black

Figure 11. Samples of heated Burlington chert. The coloring and fractionation can be noticed more clearly in some samples than in others, especially in the 600°C column.



but is considered very pure (Encyclopædia, 2014). The Hopkinton and Burlington Formation chert are mostly white and light gray, with a couple darker rocks added into the samples.

However, after the chert was heated in the ovens, a change in color was seen (Figure 12). Some samples remained the light gray with perhaps a little darkening (to Gley2 7/5PB or 6/5PB), but many of the rocks showed pink, red, and sometime a red-orange mottling (in the ranges of 2.5YR 7/ and 8/, as well as 5YR 7/ and 8/). Some only had patches of these colors but a portion of the samples were completely pink. During my previous research into heat treatment and upon consultation with Dr. Heinzl, we determined that the coloration was likely a result of oxidation. Oxidation commonly occurs in rocks when heated, as the oxygen levels change. A similar example is when iron turns red and rusts when it comes into contact with oxygen and water for long periods of time. The sand and soil used to test the samples also experienced a similar result.



Figure 12. Two pictures show the before and after versions of a piece of chert that I tested in the lab, and the coloration differences between the two.



For the experiment, quartz sand and Iowan Tama Series surface soil were used to cover the samples so that they were not in contact with the tin or porcelain containers. The oxidation also affected both the sand and the soil. The dark brown, organic rich soil turned to a much drier, light brown after its first round in the oven and then to a red-brown after its second round. The quartz sand was originally a very light tan, almost white, color, but after subsequent heat treatments it turned pink and then red. Flakes of rock that broke off of the samples in the oven also mixed with the soil, and especially with the sand, as it was heated. This coloration change in the containment medium was an interesting observation through the experimentation. Since this was unusual, I ran chemical testing of the quartz sand to see if I could find any other chemical changes in its composition.

Fracturing and the ease of fracturing was another aspect that changed between untreated and treated chert samples. Untreated, raw chert was hard to break into smaller pieces and did not fracture into neat pieces. Samples heated in the 300°C and 600°C ovens fractured much easier and sometimes they broke while being heated. The main reason for this accelerated fractionation was the concentration of heat and the temperature. Chert heated in the 300°C oven only had about one fourth of its samples break during heating. When they did fracture while in the oven, it was generally one or two chunks that separated from the main rock. Once out of the oven and cooled, I was able to break them into smaller pieces by hand – something I could not do with the raw chert. The 600°C oven had a greater propensity for fracturing. Around half of the samples tested in the 600°C oven fractured while being heated, and often half the original rock would break into multiple small pieces. Upon cooling, these samples were even easier to break by hand than those tested in the 300°C oven. These fracturing results provided interesting information regarding heating the chert in practical ways.

This heightened extent of fractionation would not have been useful for stone tool use. One of the necessities of stone tool use is durability; the tools must be able to withstand multiple uses in order to be useful. If a stone breaks after one use, as these 600°C oven samples most likely did, it would be seen as poorer quality and less useful to the Native Americans. Without a good quality chert, they needed to continue searching for a better quality chert to use for their stone tools. Therefore, heating the chert to this degree would not be useful and the raw material was a better choice for tool creation.

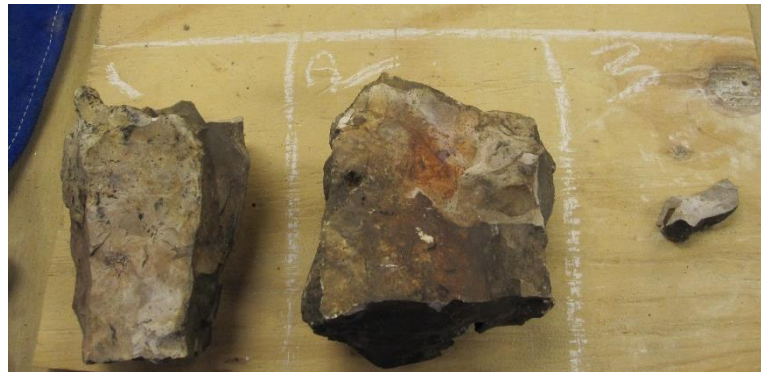
Along with the larger samples used in the 300°C and 600°C ovens, I also heated chert fragments in the 250°C oven. These were fragments that broke off while I was reducing the size of the larger pieces of chert. Testing these fragment samples allowed me to observe the effects heat had on smaller pieces of chert. I did not find any significant color or fracturing changes in the fragments. The samples either stayed their original color or turned a slightly darker grey and they did not break into separate pieces. However, since the Native Americans would have more likely heated bigger pieces of chert and then used the enhanced fracturing rates to create their tools, it is unlikely they heated fragments of this size.

Field Experimentation

Despite the limited experimentations we conducted in the field setting, we gained steady results. Since there is a limited amount of results, they cannot be taken as fully representing field experimentation. That stated, the field experiment results varied from the laboratory results in several significant ways and that could provide some interesting insight into the effects of Native American heat treatment.

Unlike the laboratory tested chert, the field tested chert did not show some of the more drastic qualities. The field tested chert tended to stay a more grayish color with tinges of pink, orange, and red (Gley 6/5PB and 5YR 7/ and 8/). The rocks did not receive as much direct heat so this could be the reason why the oxidation is not as progressed as with the mottled pink or red lab tested chert. Along with a difference in coloring, the fractionation of the field tested chert also showed a milder effect (Figure 13). There was no explosive fractionation with the field tested chert like there had been in the 300°C and especially the 600°C oven tested chert. The rocks were more difficult to manually break than the lab tested chert, but they still broke more easily than the raw chert. The edges, when broken, were also sharper than the raw chert. The two differing aspects, those of color and fractionation, shed interesting light on the difference between lab and field experimentations.

Figure 13. Chert heated in the field. They show significantly less coloration change and fractionation rates.



The ways that the lab and field results contrast are logical, due to the variation of direct or concentrated heat. The lab experiment, while colorful and extreme, is not as likely a reasonable outcome as the field experiment when examining for historical accuracy. The field results, while less flashy and less extreme, most likely characterize a truer representation of what chert looked like when Native Americans heat treated it. Not all heat treated chert that has been recovered from archaeological sites have been bright red or pink; much of the chert that has been recovered ranges from white to gray to some of the brighter colors. Although not all of the recovered chert

might have been heat treated, this varied coloration range does more closely match a heated coloration range than rocks that are completely red.

The field tested chert might also have proven to have more practical use than the chert that was lab tested. The chert heat treated in the lab did obtain sharp edges when broken, but it also fractured quite easily. Easy fracturing, even though it produces sharp edges that are useful when hunting or using other stone tools, means that the tool is quicker to break. It might only last through one or two shots from a bow or scrapes on an animal hide and then it breaks and holds no more use. Heat treated chert, like the ones we tested in the field, would be harder to fracture than the lab tested, but that also means they would hold their form longer and be more resistant to fracturing while still being sharp.

The laboratory experiments on heat treating chert showed more of the results that I expected. However, it was the field experiments that produced the results that made the most logical sense when examining the chert for usefulness and accuracy. The field experiments most closely align with traits that were useful to the Native Americans – sharpness and durability. The exaggerated fracturing produced by the lab experiments would not have been as useful as tools and weapons because of their increased chance of breaking after fewer uses. Since the field experiments did provide more logical results in regards to an increased, but still useful, amount of fracturing and a varied coloration range, those results correspond more accurately to archaeological evidence. Further experiments in the field would provide a better understanding and exploration of how that chert would function as a stone tool, but from the culmination of my research the field tested chert seems the more accurate and practical of the two types.

Chemical Testing

Chemical analysis was a method I used to examine the tract elements found in the heated and unheated chert samples. By using the XRF machine and adjusting the KeV levels, I was able to find the trace elements in each of my samples. I used two powdered samples from the 300°C and the 600°C ovens, as well as a sample from the raw versions of the Hopkinton and Burlington Formations. Most of the samples were tested for 1000 seconds, at KeV levels 5, 7, 9, 12, 16, and 20. As stated before, the different KeV levels determine which elements are targeted. Silica is the main element in chert and since the KeV level 5 targets silica, among other elements, I tested the chert an additional time at KeV level 5 for 2500 seconds. I also tested the Hopkinton and Burlington chert that was heat treated in the field settings.

Table 1 shows a sample of my results from these chemical tests. The first two samples are two powdered samples of untreated, raw chert; the third and fourth samples are Burlington and Hopkinton chert heated, respectively; the last two samples in the table are field tested chert samples. What was consistently found with all samples was the high amount of silicon dioxide, which was to be expected. It is in the trace elements that the variation can be found. In the raw chert samples, the silicon dioxide (SiO_2) levels stay around 98% while trace amounts of calcium oxide (CaO), sulfur trioxide (SO_3), and potassium oxide (K_2O) can be found. After the chert was heated in the laboratory ovens, the SO_3 and K_2O disappear, the CaO is significantly diminished, and iodine (I) appears. The SiO_2 lowers by about 4% to around 94%, but the iodine levels make up for loss by jumping from nonexistent to approximately 4.8%. I was unable to determine why the iodine appeared after heating, but this is a very good starting point for further research. The

Name of sample	Date tested	KeV	Seconds	Elements (%)			
CK RAW CHRT 1 HELIUM OXIDES KV 5	6/29/2015	5	2500	SiO2 - 98.31	CaO - 1.24	SO3 - .279	K2O - .174
CK RAW CHRT 2 HELIUM OXIDES KV 5	6/29/2015	5	2500	SiO2 - 98.2	CaO - 1.3	SO3 - .318	K2O - .178
CK F1 CHRT 1 HELIUM OXIDES KV 5	7/1/2015	5	2500	SiO2 - 95.0	I - 4.76	CaO - .235	
CK F1 CHRT 2 HELIUM OXIDES KV 5	7/1/2015	5	2500	SiO2 - 94.95	I - 4.82	CaO - .235	
CK FIELD SIL 1 KV 5	7/14/2015	5	1000	SiO2 - 98.58	CaO - 1.23	K2O - .191	
CK FIELD BURL 1 KV 5	7/14/2015	5	1000	SiO2 - 99.5	CaO - .3	K2O - .207	

Table 1. Chemical composition results from XRF testing.

only chemical change occurring could be because of the oxidation, so finding a link between the oxidation of the chert and the appearance of iodine at the expense of SO_3 and K_2O might yield further results regarding the quality of heat treated chert.

The chert samples heat treated in the field experiment conditions did not show the addition of iodine. The SiO_2 and CaO levels stayed steady, while the SO_3 disappeared and the K_2O levels rose slightly to compensate the loss. The absence of the levels of iodine that showed up in lab tested results may be linked to the lack of extreme oxidation. Like the reduced coloration and fracturing changes, the lack of iodine may be attributed to the milder oxidation. However, I was not able to precisely prove that, so this provides another facet of study for further research.

VI. Cultural Analysis

The cultural portion of my research applies the conclusions from my scientific research to my cultural research from Native American tribes located near these deposits. I used both sets of research – geological and anthropological – to draw conclusions as to how the higher quality of these lithics affected Native American trade or prosperity. In order to accomplish this part of my research, I investigated how chert played a role in Native American trade and how the quality of chert affected trade patterns. Specifically, I looked at the Oneota tribe because they would have been one of the tribes using the Hopkinton and Burlington Formation chert most extensively.

Iowa was the geographical center of the Oneota culture and had the presence of the Mississippi River and many other smaller stream systems to support it (Straffin, 1972). The presence of these water systems gave them access to a natural trade system; cultures gather

around water sources and they help form routes along which trade is easier than areas without rivers. Sites in southeast Iowa, such as the Kingston site mentioned previously, contain artifacts that suggest a trade system – these were artifacts that would not have naturally occurred in the area or were reminiscent of other cultures. If they were trading, they must have been trading with someone, most likely one or more of the other Plains and Middle Mississippi tribes (Straffin, 1972).

Along with the caches of artifacts, seasonal shifts can also explain trade connections with other cultures. Rockshelters, which were caves used in rituals, appear to have also been used for winter camps in order to hunt deer and bison, as well as to find more lithics to use for tool creation. These rockshelters were typically located to the west and could have been an opportunity to make connections with other tribes. These excursions could also have been used as meetings to swap tools, food, or other items and thereby complete trades and further cement trading relationships. As the Oneota were well spread out in the Midwest, they probably traded with other Oneota cultures (Theler and Boszhardt, 2006).

The Oneota did not have cars, trucks, or hauling crates – what they transported, they had to carry on their backs or in their arms. Larger lithics would have proven unwieldy and extremely heavy to haul, so they were often worked into smaller pieces of the highest quality near their source. Since heat treating most likely occurred before the rock was chipped into tools, it is also likely that the heating occurred near the raw sources as well (Morrow, 1994).

Concentrations of burned earth and significantly used fire pits in the Kingston Oneota site may be related to the firing of lithics (Straffin, 1972). This placement is logical because the site is located along the Mississippi River in the southeast part of the state, near the Burlington Formation outcrops, where the Oneota would have gathered chert. When examining the delicate

fracturing of the chert samples I heated in the 600°C oven, I surmised that this easy fracturing would not have been very helpful since the tools might well break after the first use. The ease of fracturing would cause this chert to wear out faster and be abandoned soon after the Oneota travelled away from the raw source. Better quality chert would have better durability and could be sharpened several times, leaving flakes farther and farther from its source material (Morrow, 1994).

This higher quality chert would also have been very valuable to other tribes who did not have access to high quality material. Better chert meant better tools and a subsequent increase in hunting profits or gleanings of plants; they no longer needed to slow down to create more tools to make up for the rapid breaking of old ones. In order to obtain higher quality chert they would trade more for it, and the Oneota who have access to it would be more willing to carry it to them. Areas more likely to have lower quality chert were those in the northern portions of Iowa, including the Hopkinton Formation chert that I studied, while the southeast provided the high quality chert from formations such as the Burlington Formation (Morrow, 1994). A tangible example of how the quality of the chert affects its use is its wide spread presence. The Hopkinton Formation from northeast and east-central Iowa is rarely seen away from its source while the Burlington Formation chert is the most widespread lithic in the whole state (Morrow, 1994).

From my literature analysis on heat treatment, heating was mostly used to increase the quality of chert. If it did not provide some kind of benefit, it would not have been worth the firing and lengthy periods of heating and cooling. Since chert like that found in the Burlington Formation was already of high quality, the Oneota might not have used heat treatment as much with regards to that chert. On the low to medium quality chert, however, heat treatment may have been used more often in hopes of prolonging the durability and usefulness of chert from

Silurian Formations, such as the Hopkinton Formation chert that I used in my experiments. The tribes who used those lower quality chert still would have desired a higher quality and traded other tribes for them, since that meant less time spent on heat treating rocks. The Burlington Formation chert is of unusual high quality and that can be evidently seen in its widespread presence, lending credence to the theory that it inspired larger trade systems and forged connections between Oneota tribes.

VII. Summary

The purpose of this study was to evaluate how the Oneota tribe in eastern Iowa used and changed the natural chert in their area in order to draw conclusions about how this affected their culture and trade systems. With this information, we can further interpret how Native American tribes interacted and how they survived and lived during their time. Their adaptation of the natural resources they found sheds light on how their societies changed and adapted to different subsistence patterns. The significance of this research can affect how past Native American tribes are interpreted, and how their innovations are viewed. Examining how the Oneota used heat treatment can open avenues of research in which to study how heat treatment has been used across the world in many different cultures, providing insight into the adaptation of humans throughout time.

Through my research, I aimed to contribute data to a growing database of Iowa's research on chert as well as to contribute to the geoarchaeological field of study. My methods of testing the rock samples in both lab and field settings added a new method and a combination of experimental processes to past research. Despite my limited field experiments, I was able to

come to several conclusions on how heat treatment changes the quality of chert. Extreme heating would not have been very useful because it resulted in too much fractionation, but my field results pointed to heat treatment more in line with the samples being heated in the 300°C oven. The results from the chemical testing provided some interesting reactions, which could be cause for further research into how the oxidation of heat treated chert affects its chemical composition. My field testing was limited to a few experiments, but this provides an avenue for future research into the accuracy and methods of field experiments. Further exploration in field experimentation would be a good next step in discovering exactly how the Native Americans heat treated their chert and the specific qualities they were specifically looking for.

Being able to link the very geological, scientific methods that I used in testing the lithics to the social scientific research into Native American trading culture gave some insight as to why the natural resources in eastern Iowa became as widespread as they did. Trade between Native American tribes would have affected how they spread their social culture as well as their material culture. The Oneota tribes are known to be widespread across the northern Midwest, though they differ from region to region, and these high quality lithics might be what separates this Oneota tribe from the others. My research explored how the physical and chemical properties of lithics can create new interpretations or insights into culture, which further research into could create an interdisciplinary study that reveals intriguing links to Native American culture. This interdisciplinary area that I conducted my research in linked the quality of chert to trade patterns of the Oneota and that impacts future research into how Native American's traded and lived hundreds of years ago.

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